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ABSTRACT

This chapter elaborates on some guidelines for and methodological variations of action research approaches to the study and creation of change in mathematics education. Focus is on the interplay between evolving research on and change in mathematics practice that occurred in schools and classrooms of experienced high school mathematics teachers. It begins with a discussion of two issues: the role and relationship of the teacher and the researcher, and the nature of the knowledge that is generated by practitioner research and how it is made public. Through examination of these two issues, two of the dilemmas posed by the action research paradigm are explored and some guiding principles for the design of action research projects and the specific methodological approaches taken in three particular studies are described. Offers a critical perspective on any action research project. (KHR)

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15 Paradigms for Teacher-Centered, Classroom-Based Research

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The terms *action research*, *teacher research*, and *collaborative action research* have been used as umbrella terms to cover a wide range of classroom-based research activities. The images for teacher research include a reflective process aimed at the professional development of the individual; an approximation of university research that is carried out by teachers; a new methodology with its own epistemology, standards, and questions; or a cyclic process of problem identification, action, and reflection aimed at changes in practice. Just as the history of action research has its roots in an agenda for social change through practitioner research, a common thread among these images is the study and creation of practice-centered change. In this chapter, we elaborate some guidelines for, and methodological variations of, action research approaches to the study and creation of change in mathematics education. We focus on the interplay between the evolving research on, and changes in, mathematics practice, which occurred in the schools and the classrooms of experienced high school mathematics teachers. This is not to suggest that the only model of classroom-based research is action research (see, e.g. chaps. 9, 11, and 13, this volume), but merely to state that teacher research of necessity occurs in classrooms in schools.

We begin with a discussion of two issues that have become particularly salient for us as researchers: the role and relationship of the teacher and the researcher, and the nature of the knowledge that is generated by practitioner research and how it is made public. Through these two issues, we identify two of the dilemmas or tensions posed by the action research

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paradigm. Then, we describe some guiding principles for the design of action research projects and the specific methodological approaches taken in three particular studies. We report briefly on the results of these studies in order to illuminate some of the significant characteristics of this methodology. Finally, we conclude with some remarks intended to offer a critical perspective on any action research project.

THE ROLES OF TEACHERS AND RESEARCHERS

Traditional books on the methodologies of qualitative research acknowledge the crucial role played by the relationship between the researcher and the subjects of the research. Researchers are admonished to establish rapport with field informants while simultaneously being cautioned against the bias that can result from the failure to maintain an "objective" or neutral stance. More recently, both feminists and postmodern qualitative researchers have criticized the very notion of an "objective standpoint," arguing that it leads to an object treatment of human subjects while at the same time hiding the human side of the researcher (Fine, 1994; Reason, 1994). This has led some researchers to engage in more collaborative relationships between researcher and teacher. In the work of Ulichny and Schoener (1996), their teacher-researcher team conceptualizes their research stance along two dimensions, one of relationship and one of action. They saw the relationship between the researcher and the teacher as situated along a continuum from relative strangers to mutual friends.

In terms of action, Ulichny and Schoener (1996) viewed the researcher as positioned along a continuum from distant observer to full participant in the work under study. The teacher, on the other hand, though a full participant in the classroom work being studied, may be only a very distant observer of the research project, the data analysis and interpretation, and the communication of the results. Although there is much literature on collaborative research, much of it is reported only in the voice of the researcher and only on the results of the research from that perspective. In their study, Ulichny and Schoener provided two distinct interpretations of the teaching and learning questions that were central to the research and a view of the dynamic evolution of the relationship between researcher and teacher. When the teacher shares the role of researcher, classroom-based research moves from the teacher being the passive object of study to an active state in which the teacher is a participant in the

research process. This participation leads to a greater role for the teacher in defining researchable questions, gathering and interpreting data, and communicating results. It also leads to changes in the relationship between the researcher and the teacher. This relationship needs to promote the development of knowledge through shared dialogue, and this knowledge then lives in the joint world of theory and practice. Glesne and Peshkin (1992) suggested that an increased emphasis on issues of power and control in the research process has led to the emergence of alternative modes of qualitative research, such as action research.

Some investigators have advocated a model that replaces the university researcher with the teacher, as an investigator of his or her practice. This shift potentially enables the teacher's voice to be heard fully and gives recognition to the creation of new professional knowledge by practitioners (Tripp, 1990). At the same time, it alters the research project and process fundamentally by posing different questions and by redefining what data are collected and how they are analyzed and reported (Glesne & Peshkin, 1992). Furthermore, as teachers become the "subjects" of their own research, the research process necessarily becomes one that is self-reflective. The cycle of problem identification, action, and reflection encourages changes in teachers' beliefs and in their classrooms (Calhoun, 1993; Oja & Smulyan, 1989).

Action research and teacher research shift the knowledge base for teaching from one that is built primarily on university-based research and then applied in classroom practice to one that recognizes teachers as generators of knowledge from practice. An essential characteristic of this shift in the knowledge base is not merely the location of the site (i.e., the classroom as a target of a technical rationalist approach to research grounded in the university), but rather the centrality of the involvement of the teacher as a poser of researchable questions, collector of data, and generator of knowledge. This then leads to one of the fundamental dilemmas posed by action research, which is how to account for the stance and perspectives of the teacher-researcher who is researching her or his own practice.

KNOWLEDGE ABOUT TEACHING AND LEARNING

The primary purpose of much traditional academic research is to generate theories and test hypotheses, thereby creating new knowledge. Action research, on the other hand, often has as its goal the transformation of practice (cf. Goswami & Stillman, 1987; Noffke & Stevenson,

1995; G. Wells, 1994). Other goals of action research include closing the gap between research and practice, providing opportunities for teachers' development, enhancing the professional status of teachers, and investigating the solution of practical problems in schools (hence, the word *action* research). In their work, A. Feldman and Atkin (1995) made a distinction between contributing to the knowledge base of the academy and developing greater wisdom about educational practice. This claim is built on an epistemological framework that draws on an understanding of the nature of professional knowledge in fields other than education. By analogy, Feldman and Atkin argued that, "much of the wisdom associated with the intelligent use of practical information lies in a particularized understanding of the circumstances in a specific classroom (and, indeed, of the particular teacher)" (p. 131). These case-based, person-specific understandings of particular events, people, and conditions are built and developed by educational practitioners through the action research process.

Cochran-Smith and Lytle (1993) were both cautionary and critical of the notion that the structure of knowledge as practical wisdom is only experiential and pragmatic and argued that such a view may well lead to the devaluation and marginalization of such knowledge. They asserted that teachers do bring a theoretical framework to their research questions, analyses, and interpretations. These frameworks encompass knowledge of content, pedagogy, curricula, characteristics of learners, and educational contexts, purposes, and values. According to Cochran-Smith and Lytle, "if we regard teachers' theories as sets of interrelated conceptual frameworks grounded in practice, teacher researchers are both users and generators of theory" (p. 17). They went on to argue that those teachers who are researchers in their own classrooms can and do construct knowledge about teaching, learning and schooling.

One of the current challenges of action research, according to Noffke (1994), is to clarify if and how action research can contribute to the traditional knowledge base of educational research or if it is, "a new form of research whose methods, methodology, and epistemology are now being clarified" (p. 16). Elliott (1991) argued that in action research, theory is derived from practice and is constituted by a set of abstractions and generalizations about it. This contrasts sharply with a technical rationalist view that sees practice as the application of theories and principles that are understood prior to engagement in practice. According to Schön (1995), the epistemological foundation of action research is precisely a rejection of a technical rationalist approach to knowledge and a valuing of "knowing-in-action." This knowing-in-

action is tacit and implicit in the actions of competent professionals as they make judgments and perform tasks in an everyday setting. Schön suggested that there is an "epistemology of practice that takes fuller account of the competence practitioners sometimes display in situations of uncertainty, complexity, uniqueness, and conflict" (p. 29). However, knowledgeable practitioners are often at a loss to produce adequate descriptions of what it is that they know. By reflecting-in-action, the practitioner restructures her or his understanding of the problem situation and of the strategies of action that she or he has been using. According to Schön (1983, 1987, 1995), reflecting on reflection-in-action makes explicit the action strategies, assumptions, and problem settings that were implicit in reflection-in-action. This, in turn, can lead to the critique and testing of strategies ("Why didn't that work?" or "What should I try next time?"), assumptions, and problem settings implicit across a range of situations. Drawing on Dewey's notion of inquiry, Schön argued that action research becomes generative when it moves beyond the solution to a particular problem to the generation of new problems. This then leads to the generation of new knowledge and multiple cycles of inquiry, which we illustrate in FIG. 15.1.

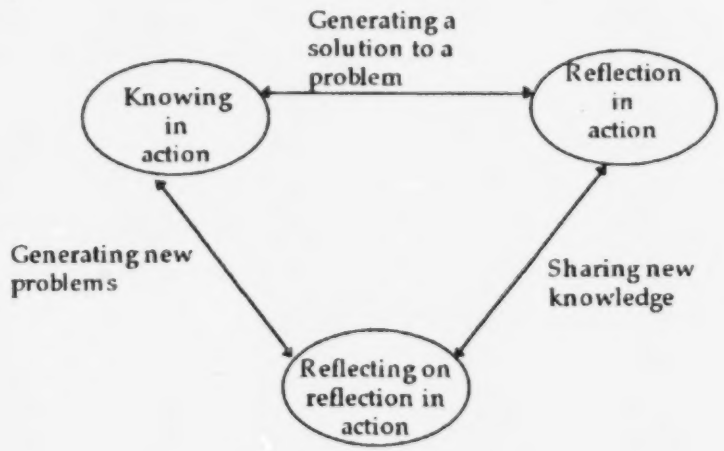

FIG. 15.1. Cycles of inquiry through teacher research.

The steps of reflecting on reflection-in-action and the generation of new problems are what distinguish the knowledge gained from action research and the knowledge held by an individual who is a "good reflective practitioner." The sharing of knowledge, the generation of

new problems, and the active application of knowledge in practice lead to the close intertwining of theory and practice.

Increasingly, this teacher-generated knowledge is finding new forums for presentation and publication (Burnaford, Fischer, & Hobson, 1996; Cochran-Smith & Lytle, 1993; Goswami & Stillman, 1987; McNiff, 1993; Raymond, Rafferty, & Dutt, 1996; G. Wells, 1994; Zack, Mousley, & Breen, 1997). According to Schön (1995), action research suggests that teaching is a new form of scholarship and, as such, must lead to new categories of scholarly activities and the "building up [of] communities of inquiry capable of criticizing such research and fostering its development" (p. 34). A fundamental dilemma posed by any action research project, then, is to understand how to move beyond the particular story told by a skilled reflective practitioner in order to understand, critique, and foster the development of the new knowledge that is embedded in the practice of teaching and learning and to nurture the expression of that knowledge in new forms and by new voices.

GUIDING PRINCIPLES

The centrality of the relationship between the researcher and her or his practice and of the nature of the knowledge that is generated form the basis of the two most significant characteristics of action research:

- Its primary purpose is to simultaneously study and generate knowledge about the very practice that it seeks to change.
- The study is carried out by the practitioners (in varying degrees of close collaboration with university researchers) rather than by an outside group of researchers.

Because of these defining characteristics, action research does not fit neatly within those research frameworks that tend to be hypotheses-testing or hypotheses-generating studies. Above all, the goal of action research is to be action generating. As such, projects designed with this methodological approach are much more likely to guide practitioners toward practical next steps that can be taken to resolve a specific local problem and are somewhat less likely to provide findings that will guide a major rethinking of policy, curricula, instruction, or theories of learning. The knowledge gained by action research tends to be local, often at the level of a

particular element of instructional practice in a particular classroom or at the level of an issue that affects several groups of participants (such as teachers, parents, and administrators) in a school building.

With these two central characteristics in mind, we offer the following five guiding principles that are intended to uncover some of the assumptions underlying action research, to assist in the design of an action research project, and to provide a perspective from which to take a critical view of the results of action research:

Systematic Cycles of Inquiry. Because action research studies simultaneously both teaching practice and the changes taking place in that practice, the research process itself should be characterized by the intertwining of research questions that are refined and reformulated as changes take place and data are collected and analyzed. New questions emerge, new actions are taken, and new data are collected. The systematic definition of emerging queries and the systematic collection of supporting data throughout these cycles of action likely will lead to results that tend to be perceived as supporting or challenging the changes in practice and as evolving continually into better understandings of practice.

Grounded in Evidence Gathered by Practitioners. In action research, data gathering and analysis should be seen as ongoing and mutually informing the research questions. These cycles of inquiry should inform and modify the participants' roles in the study and should support the changes that occur in the context of the study. Although the final product of a qualitative study may be documentation or the generation of a framework to elicit understanding, the product of an action research project should include the change of practice based on the evidence gathered by the practitioners. As noted previously, action research tends to be defined somewhat locally. However, within the limits of this local definition, be it within a single classroom for a short period of time or across several classrooms within a school, the design of the project should support thorough collection and analysis of the data by practitioners.

Generative of New Questions. The action researcher is in interaction with and transforming the problematic situation. In the spirit of what John Dewey called inquiry, action research proceeds from a problematic situation to the resolution of the problem to the generation of a new problem. This new problem comes in combination with changes in the context that result from interactions with the original problematic situation. Hence, the test of

a cycle of action research is not only a critique of the interactions and that transformation of the problematic situation, but also a critique of the value of the new problems that are generated.

Generative of Shared Knowledge. Often, the stories of teacher-researchers are told as the particular knowledge gained by teachers in their own classroom setting. Indeed, at the extreme, one could claim that teacher research is merely reflective practice. Though we recognize that reflective practice is certainly a highly desirable attribute of a practitioner in education, we would argue that merely reflecting on one's own practice and acting on those reflections are not sufficient to contribute to the educational community's knowledge about teaching and learning and will not lead to powerful ideas for growth and change. An essential element of effective action research is that the findings of that research become generative of new shared knowledge for the larger educational community. However, we are not suggesting, as is seen later, that the forums for sharing teachers' knowledge should be limited to the traditional currency of the academic research community. Rather, new forums and new forms for shared knowledge will emerge as teacher-researchers gain new professional voices for speaking about what they have learned about their practice. The audience for action research products should include both theoreticians and practitioners because the results of the research should stay within the overall paradigm of a close intertwining of theory and practice.

Diversity and Multiplicity of Participants. Action research is characterized by the involvement of the participants as researchers. Classroom teachers move from hosting university researchers in their classrooms to becoming members of the research team or the researcher. In addition, the action-oriented researcher seeks to study a system and to introduce changes into that system simultaneously. Whereas the observer who documents change ordinarily guards and values the distance that she or he keeps from being involved in the setting, the researcher in an action research project participates directly in the project both as a participant and as a researcher. To balance this lack of distance by an individual researcher, action research projects should employ several participants with a variety of viewpoints about the project as members of the research team. Such diversity and multiplicity across both participants and settings serve to strengthen the validity of the research findings.

These guidelines are intended to suggest the potential strengths of action research approaches as well as to indicate cautionary notes for those who design and participate in such

projects. In the next section, we describe three of the various methodological approaches that we have used as practitioners who study the very systems we wish to change. The second author of this chapter is a university researcher and participated in varying roles in each of these studies. In addition, this chapter was read and critiqued by Barbara A. Shelly, one of the teacher-researchers in the first study and a codirector of the second study.

METHODOLOGICAL VARIATIONS WITHIN ACTION RESEARCH

The methodology of action research always is situated in a particular context or setting and is directed toward actions to be taken by teachers and other members of the community of practice, often in a collaborative role with university researchers. As noted earlier, we describe three methodological variations of action research, followed by details of the actual studies. Each variation is recounted in terms of:

- The purpose of the study.
- The role of each of the players in it.
- The data collection and analysis processes.
- The presentation of the findings.

Variation 1

In the first approach, two teachers and a university researcher (the second author) defined their collaborative inquiry as the examination of two classes whose teachers were beginning the process of changing their instructional routines. The purpose of the research was twofold: to document the effects of these instructional changes from the perspectives of the students, and to continue to shift the normative teaching practice from a traditional, passive, lecture mode to one that involved the students actively. Thus, the focus of the research was on changing the culture of two classes. Because the research was guided by the purposeful decision to veer away from what had been well-established practice, both the school's administrators and the students' parents were informed about the intent of the research. The students were asked to sign consent forms, so that they, too, were aware that their teachers were making and studying changes that would take place in their classes.

Whereas the university faculty member had a background in qualitative research, the teachers' roles as researchers were evolutionary. At the beginning of the study, the roles were defined more traditionally. The university researcher's initial role was primarily that of an outsider observing and documenting both the teachers' and the students' actions and voices in the secondary mathematics class. However, as data about the students were collected and as the teachers and the university researcher discussed the data and formed conclusions that shaped the actions in the next day's class, the process of the study left the more traditional, observational, research paradigm and became aligned more closely as an evolving, collaborative relationship for the researcher and the teachers. The university researcher progressed from observer to participant by designing instructional materials, whereas the two teachers shifted from solely classroom practitioners to observers and researchers of classroom life. The teachers became full partners in establishing research priorities and in collecting and analyzing data. The university researcher began to play a role in designing the strategies that would bring the desired changes into the classroom.

The study evolved into one that documented classroom reform as experienced by the students and provided data to guide the teachers initiating and revising the reform efforts (Tinto, 1993a; Tinto, Shelly, & Zarach, 1994a, 1994b). Data collection techniques focused on capturing the students' voices. As the students realized that their perspective was playing a part in the shaping of the class, they, too, began to see themselves as participants in the research. The outcomes of the 2-year research study were presented at conferences related to practice for teachers and at research conferences and provided evidence for the creation of a large-scale teacher development project (Tinto, Shelly, & Zarach, 1992, 1993; Tinto, Zarach, & Shelly, 1993). In this manner, the study reached the joint goals of speaking both to theory and to practice.

Variation 2

In the second action research variation, the research study was initiated as a part of a continuing staff development effort. It was designed as a model of collective inquiry, where each project teacher would be involved in her or his own small-scale study. The intent of the project was to use these small-scale research projects as vehicles for moving teachers beyond reflective practice to initiating and sustaining changes in how they teach. The project's codirectors (who included the two teacher-researchers from the first study and the second

author) acted as coaches to respond to questions about conducting research, but they did not participate actively in the resulting studies. The function of the university researcher was defined as that of mentor, assisting the teachers with the development of questions or facilitating dialogue among them that would help them to identify a research focus. Greater details on how teachers go about designing an action research project can be found in Altrichter, Posch, and Somekh (1993), Elliott (1991), Hubbard and Power (1993), and Mohr and MacLean (1987).

Each teacher defined an area of inquiry and carried out her or his own study individually. The teachers' questions were targeted at examining aspects of specific instructional strategies. The project emphasized the systematic gathering of data and learning how to "look" at a class from the perspective of a researcher as well as a teacher. A summer institute for the participating teachers included classes on qualitative research methods, and time was given during the academic year to helping shape the questions being asked by the teachers. For the participating teachers, it was very important that the "doing" of the research study was seen as manageable, so that the dual role of teacher and researcher was necessary only for a very specific part of each teacher's day. On the whole, data collection methods were those that were seen by the teacher-researchers as being integrated closely with classroom instruction and assessment (Tinto, 1996a, 1996b). These methods involved collecting students' writing or recording students' talk. In these small-scale studies, the teachers did not take on the role of advocate completely. In fact, many of the teachers were somewhat skeptical of the instructional strategies that they were implementing. The classroom context was one of experimentation, with the teacher-researcher developing her or his understanding through participation in the research process.

The power of the research process to change practice was seen in the collective reporting of research efforts by the participating teachers (Tinto & Shelly, 1996). Although the focus of each research study was necessarily narrow, the overall significance was heightened by the number and the diversity of the research sites. As a consequence, the project moved from being a story of good practice in one classroom to becoming a model for breaking traditional teaching routines in many classrooms. The results of these studies were presented by the teacher-researchers at local, regional, and national forums for mathematics teachers (Tinto, Shelly, Zarach, & Graver, 1995).

Variation 3

The purpose of the research in the third variation was to respond to a perceived need of a local school community to improve the quality of the mathematics education of students. Much of this concern was focused on perceptions about students' failure rates—which students were failing, whose students were failing, and why they were failing. In this case, the goal of hearing the many perspectives present in the situation was a major force in defining the data collection methods. Students, parents (among them the second author), and teachers were involved from the beginning as central players in the study. Interviews were deemed essential in order to gather each person's words (and this included administrators' voices as well) in order to help build a collective view of the problem. To establish mutual trust and, ultimately, common ownership of the findings, it was critical that the researchers not be outsiders to the community. To address concerns about potential biases in data collection and analysis, the researchers needed to represent each segment of the community and to work together in defining the focus of the study, developing interview questions, and analyzing the data. The relationship between the participant-researchers and the community members at large was seen as a significant issue in the research process. The results of the data collection and analyses were presented to the community as a collective understanding of the various perspectives on the problem. This joint ownership of the process and its outcomes helped to ensure acceptance of the findings by the larger community.

In the next section of this chapter, we describe more fully each of the action research studies whose methodologies were discussed earlier. These three studies are used to explore and illuminate:

- The relationship between the university-based researchers and the teachers.
- The nature of the research questions posed.
- The changes that took place at the level of the individual teacher and in a departmental setting.
- The articulation of the results of the research.
- The emerging voices of the teachers.

These three studies show a range of relationships between teacher and researcher, from collaborating with a university researcher in designing the focus of the research to

participating in a network of teacher-researchers reciprocally defining the questions, gathering the data, and interpreting the results. Through their engagement in this research, teachers made changes in their own classroom practices and in those of their school. At the same time, they participated in local and national forums for communicating the results of their work. The first action research study focuses on the professional development and their emerging roles as teacher-researchers of two experienced secondary mathematics teachers, whereas the second study shows how this development led to the creation of a larger network of teacher-researchers. The third study focuses on school-level changes that were motivated through questions brought about by the changes in practice of these teacher-researchers.

TEACHERS AS COLLABORATIVE RESEARCHERS FOR CHANGES IN CLASSROOM ENVIRONMENTS

During a local conference on using technology in the classroom, two secondary mathematics teachers, one from a suburban district, the other from an urban district, and a mathematics educator (the second author) began to talk about teaching practices in the classroom. Though both teachers were perceived by parents, students, colleagues, and administrators as exemplary teachers, both were dissatisfied with their current classroom culture. Both teachers were teaching computer classes also and had observed the startling contrast in students' engagement between their computer classes and their mathematics classes. The teachers noted that their computer classes were more in keeping with the standards of the National Council of Teachers of Mathematics (NCTM, 1989) than their mathematics classes were. Unlike their mathematics classes, the computer classes were characterized by the active involvement of the students in the learning process. Problem solving was the focus of the activity, and the teacher played the role of facilitator, rather than authority.

Both teachers wanted to employ more active learning strategies in their mathematics classes and to implement technology. They expected such changes to impact the culture of their classes. Realizing that they had no obvious external support for making such changes, they decided to join with the university researcher and to document their efforts. They wanted to be able to answer the question, "How will we know if we have made a positive difference in the learning environment for students?"

A collaborative teacher-researcher team was formed. The teachers brought to this team expertise in technology and an interest in group work and writing in the classroom. The mathematics educator became a mentor in the research process. She listened to the teachers' reflections about classroom practice and helped them to formulate questions for their students in order to gather the data that would inform their inquiry. Over the course of 2 years, the teachers implemented a number of changes designed to involve their students actively in learning mathematics. These changes included using cooperative group strategies, problem solving with technology, teaching the "big ideas," and encouraging the students' written expression of mathematical reasoning. The teachers hypothesized that the students who were involved in these activities would learn to think mathematically. Together, the team formalized specific questions such as:

- What types of cooperative group experiences are useful in teaching specific mathematics content?
- How does the use of technology facilitate students' conjecturing?
- Do these changes in instructional strategies support more active class involvement for students?

To document their efforts at changing the learning environment of their classrooms, the team identified the kinds of data that they would collect. Seeing change as a year-long process, the team decided to capture data by collecting students' journals and learning logs, audiotaping students' talk during group work, and videotaping both whole-class and small-group work. Initially, the teachers focused on ways to document change. They needed to describe what went on in their classrooms. Students responded to journal questions such as, "For me, a typical math class is. . . . " and, "Math is like. . . . ." As the teachers heard the voices of the students and saw how the students responded to the innovations, they moved from merely trying to document changes to trying to understand more fully the reasons for those changes.

The team reexamined the students' journals and learning logs to identify the sources of authority in the classroom. As the teachers read the journals and analyzed the students' responses, they found that in the beginning of the year, students wrote about mathematics class in terms of the teacher. Several months later, the students were describing the classroom routine in terms of their own actions. Early in the year, the students had articulated a transmission model of teaching and learning. This led the two teachers to rethink the group

structures that were used in class. They moved from group models where students were assigned special roles to a model that promoted conjecturing on the part of each student. Data were gathered in the form of students' written reactions to photographs taken during group work. Responses to the "What's going on here?" query gave the teachers evidence that the students were beginning to see themselves as engaged in the process of doing mathematics. Listening to the audiotapes of group discussions and reading the transcripts helped the teachers to understand the dynamics of small-group interactions. Thus, the teachers felt increasing confidence about their strategies for moving the students toward a model of more active participation in their classes.

Though both the teachers and the university researcher benefited professionally from the action research and their interactions on the research team, the impact of their work had potential beyond their own professional development. One of the results of their study showed that effective, small-group interactions were characterized by conversations in which students' talk included explanatory remarks, students shared the role of expert, social talk was brief and noninterruptive, and students gave and received genuine mathematical responses for help and feedback (Tinto, Shelly & Zarach, 1994a, 1994b). The teachers and the mathematics educator were invited to join a national panel of researchers at the National Science Foundation Catalyst Conference in 1991, which provided further validation for the teachers of their roles as researchers and collaborators. At the conference, the audience of university-based researchers noted that the perspective of the teacher in the classroom is central to developing an understanding of the teaching and learning process in mathematics classes. It became apparent that this perspective becomes available only when the teachers are active in the research process—when, in fact, they are researchers. The teachers reported that they gained an understanding of the potential of educational research. Rather than seeing such research as distant and distinct from the classroom, through their ownership of the research questions and the data, they came to value classroom-based research. This led to the development of the collective action research project, described next.

COLLECTIVE ACTION RESEARCH FOR CHANGE IN TEACHERS' PRACTICES

In the summers of 1993 and 1994, 42 secondary mathematics teachers from 15 school districts began a multiyear project to build a local network of secondary mathematics educators rethinking their practice. The teachers came from rural, urban, and suburban middle schools and high schools. Part of the selection criteria included support from school building and school district administrators and evidence that the teachers had a history of commitment to professional development activities. Preference was given to pairs of teachers from the same school. When small rural schools were involved, teams could be teachers from neighboring towns.

These teachers were asked to rethink their practice but were not told what to change. Instead, they were asked to look at the teaching routines that they had developed over the years, select a part that they were not satisfied with, and begin to change that piece (Tinto, 1993b; Tinto, Shelly, & Zarach, 1993a, 1993b, 1994a). They were challenged to collect evidence so that they would know if their innovations were effective. During 4-week summer workshops, the teachers engaged in exploring mathematics, learning about computer and graphing calculator technologies, and adapting new strategies to involve students in mathematical thinking. The learning opportunities for the teachers were created as models for best practice and were discussed as part of the workshop.

The summer workshops also involved the teachers in discussions of their teaching routines and of how to go about documenting what takes place in their classrooms. The teachers commented that although they continually gathered informal data that played a role in their thinking about the students and about themselves as teachers, they did not gather these data in any systematic fashion. The teachers realized that many of the questions they had about their practice could not be answered by the conventional data (tests, quizzes, and homework scores) that they had collected. This led to a cycle of refining their questions about the process of teaching and defining the kinds of data needed to answer these questions. The university researchers responded to this need by introducing the ideas and processes of using qualitative data as a basis for decision making. One teacher spoke for many when he said: "I found that

the research, in the collection of some kind of data which may verify that we are doing something in the right direction, is an important step."

Following the emphasis on writing suggested in the NCTM standards (1989), the teachers focused on adding new types of questions to their traditional assessment instruments. Developing questions that were open-ended and nonleading became a part of their new routine for many of the project's teachers. The systematic collection and analysis of these data were the next steps. When students responded to the teachers' beginning-of-the-year query, "When I enter math class, I . . . ," the teachers gained two important perspectives on it. First, they acquired insights into each individual student's perspective on the mathematics class, and, second, they formed a collective vision of what was defining the culture of the class from the students' viewpoint. Both perspectives then became data for the teacher-researcher in making changes in her or his classroom. In beginning-of-the-year journal entries, students spoke often about the teacher, describing very conventional roles for both the teacher and the student. The similarity of students' perspectives on the teaching routines across all teachers and schools was a powerful motivational force for teachers to begin to rethink their teaching practice. For these teachers, this type of data supported their emerging beliefs that their efforts to change the role of the teacher in the classroom were warranted.

Other teachers focused their research questions on students' discourse during group work. Many teachers, who had monitored and filtered all of the conversation in their mathematics classes, were concerned that students would solely engage in social talk. These teachers organized group work and audiotaped their students' discussions. Some teachers took the time to listen to each group conversation carefully, whereas others had the tapes transcribed and read through the transcripts. After analyzing the students' talk from several of her classes, one teacher noted, "Why did I wait so long!" She was amazed at the level of mathematical talk taking place student-to-student. It was clear that this level of conversation had not occurred when she had directed and controlled all of the discussions.

Several teachers from different schools decided to break their routine by forming student homework groups. The rationale for forming homework groups was to bring students into class, involve them in discussion, and cut down on the time that most secondary mathematics teachers spend reviewing problems at the blackboard. These groups would consist of three to four students and would be formed for an entire grading period. Homework groups would meet at the beginning of each class period, and students were expected to use the time to discuss

homework questions. If a group member had difficulty with a question, other members were expected to assist in an explanation until all of the members felt confident of their responses. The teacher would provide an answer key depending on the type of homework and the purpose of the homework. Again, teachers had many questions about this structure. Would students stop doing their homework and attempt to "piggyback" on the responses of other students? Would students engage in social talk only? Would students merely give others the answer? Would students who were handing in their homework consistently feel that the discussion groups were wasting their time? Teachers structured journal questions to hear the reflections of the students and they listened to audiotaped discussions. Each teacher analyzed the data that she or he had collected over several months. The outcome was powerful. Each teacher had come to similar conclusions about the positive impact of homework groups on their students' learning and on the class culture in general, and these teachers represented different courses and different schools. The replication of the study across different schools enhanced the power of the results for the teachers. When they presented the results to other teachers, these teachers looked at the studies as a whole, believing in the validity of the research and believing that they, too, could try this innovation in their classroom. Thus, the results became generative of new problems for action for these other teachers.

The teachers in the project were asked to present the results of their studies to each other and to their administrators. The presentation format selected by the teachers was a poster session on each research project. During the regular Saturday sessions, the teachers would display their posters during the coffee hour and time was given for them to talk with each other about the progress of their studies. At first, the idea of bringing to the public the results of their research was somewhat overwhelming. Once the poster session began, however, teachers soon realized that they gained from discussing their own study and they gained by listening to others. At the end of the academic year, teachers shared the results of their studies more formally with other teachers and administrators. The success of this miniconference prompted the teachers to present their posters at their own schools, both to fellow teachers and to parents.

The teachers stated that they felt more secure in talking with parents about the changes because they had the data to support the positive impact of their innovations. They could point to students' responses and students' dialogue to justify their changes in teaching

strategies. Later, several teachers brought their posters to a research conference on mathematics education hosted by the local university. Thirty teachers took their research studies to a session at NCTM's annual conference in 1995. Subsequently, teachers reported that although they were somewhat negative at first about the amount of time that they perceived would be involved in the work of creating a research study, finding a focus, being diligent about collecting data, and analyzing it, not only did they gain from the final results of their study, but also they learned from doing it. Many noted that the process of doing the research became a part of the process of teaching. Moreover, they began to value the research conversations that they were having with each other. One of the most noticeable outcomes of the project, for the teachers, was the development of this network of professional voices.

Not every teacher continued to do research on a regular basis in her or his classes. However, most of them have redefined their routine assessment tasks to include the collection of qualitative data. Many have stated that the routine of the Friday quiz is a thing of the past. Learning logs, group-processing forms, and homework headings provide teachers with the data that they need for an ongoing assessment of their students and their classes. As one teacher commented:

> If I am going to try something new that I am not sure about, I'll purposely collect student data. It might be a journal question or I might take pictures and ask students what is going on here? But I know that if I really want to know whether this is a good idea or not, I'll need to do something more organized, more systematic.

Thus, the project's teachers developed a new sense of creating a knowledge base about teaching practices through a cycle of posing questions, defining and gathering data, analyzing and interpreting results, sharing insights and findings, and investigating new questions.

COMMUNITY ACTION RESEARCH FOR CHANGES IN SCHOOL ENVIRONMENTS

As the teachers involved in the project described previously began to rethink their teaching practices, their classrooms began to look and sound different from conventional classrooms. This led to conflicts in one of the schools. Students and parents became aware of the

differences in teaching practice between the project's teachers and other members of the department. One evening, parents arrived at a parent-teacher meeting angry about the prior year's low test scores and the perceived inequities in current teaching practices. Some of the parents blamed the curriculum; others blamed the teachers. The teachers talked about unmotivated students and the lack of administrative support for needed materials, whereas the project's teachers tried to address the need for group work and the use of technology. The situation was rife with anger and frustration. It had the potential for dividing the faculty and the students even further apart.

The project's teachers, having found new roles for themselves as teacher-researchers, negotiated with the parents to form a task force consisting of parents, teachers, and students to study the problem. The group met and decided to interview members of the school's community. With the assistance of a qualitative researcher from the Mathematics Teacher/Researchers Collaborating for Collaboration in the Classroom (MTRC3) project, the group developed open-ended interview questions to gather the perspectives of students, parents, teachers, and administrators about mathematics at the high school. The task force asked: "What is the students' experience in mathematics at City High?" "What do parents expect?" "What do teachers experience as mathematics teachers at City High?" "How does the administrative staff view the mathematics program and how do they react to the issue of low test scores?" To honor confidentiality and to increase participants' levels of comfort with the process, graduate students trained in qualitative research methods were asked to join the project and to conduct some of the interviews with teachers and administrators. The research project took a critical turn when task force members themselves engaged in the collection and interpretation of data. Students interviewed students and parents. Parents interviewed parents and some students. Teachers interviewed teachers.

This participation helped to ensure that different perspectives about the problem would be heard and valued and that, as members of the inquiry team, all of the constituents would take responsibility for the problem. Biklen (1991) observed that qualitative research holds this capacity to build community. In finding out how each of the groups interpreted the mathematics experience at City High, the groups began to understand the broader context of concerns and expectations in which their particular view was embedded. Three themes emerged

from the interview data, and the task force began to organize its findings around these thematic issues:

- *What is mathematics?* Students and teachers agreed that mathematics is different from other school subjects in the ways in which it is taught and learned. Mathematics is perceived as distant from interpersonal relationships. Students saw it as disconnected from the real world. It was socially acceptable to dislike and be unsuccessful at mathematics, yet failure at it made many students feel that they were not smart.
- *What are the most common explanations that students, teachers, and parents use to account for problems with mathematics?* Teachers felt that mathematics classes were too large and blamed the lack of students' motivation and their prior elementary preparation for the high failure rates. Students also felt that the mathematics classes were too large and faulted teaching strategies for their failure. They expressed a need for better explanations by teachers, a better attitude by teachers toward students, and less disruption of the class by peers. Students believed that most of the problems came from students either having "math genes" or not having "math genes." Students also faulted "mixed-grade" classes for many of the problems that individual students faced. These mixed-grade classes had students from more than one grade level in the same class; indeed, some classes had students from all four grade levels in the same class. Parents expressed frustration with their inability to help with homework. Parents, too, attributed students' success or failure to "math genes." They felt that teachers held low expectations of success for many students and that teachers viewed students as either "getting" mathematics or not. Parents were concerned that problems in mathematics frequently led to problems in other courses as well.
- *How did parents, students, and teachers perceive the relationships between groups in ways that would account for the lack of communication they all felt?* Parents, students, and teachers all felt that there was too little time for teachers to get to know students in and out

of class. Teachers noted that the physical separation of the school building kept students from lingering at class but promoted good departmental relations among teachers because teachers of like content had rooms close by. Students' impressions of the helpfulness of teachers varied, as did their impressions about the positive and negative effects of student–student relationships in the classroom. Although teachers said that they welcomed parental collaboration, they noted that issues such as working parents, family instability, and hostility toward schooling were reasons they had not been successful at achieving positive relationships with parents. Parents saw such collaboration as important because of their own perceived inadequacies with the subject.

The task force met with the parent–teacher organization and then made these recommendations in each of the three areas:

- *What is mathematics?* The task force felt that it was critical to begin to change beliefs about the use of mathematics, about who should be studying it, and about the expectations of who should be successful at it. The task force recommended that all of the groups (students, teachers, parents, and administrators) should continue to engage in dialogue about mathematics at City High. Algebra should be required for all students. The task force argued against the concept of "math genes" and urged that mathematics teachers, students, and parents each take responsibility to believe that all of the students in the class can succeed in mathematics. All of the groups were adamant that more tracking would not be a solution. All of the groups must work on diminishing the distinctions between mathematics and other subjects. Writing across the curricula was suggested as a strategy that would emphasize the connections of the other subjects with mathematics. Multicultural influences on mathematics should be stressed in various courses; instructional changes utilizing technology were needed.
- *What are some possible solutions in response to the most common problems with mathematics?* Teachers and students alike argued that class

sizes must be reduced. Teachers wanted to have longer class periods as well. Students should form study groups for mathematics, and schools should offer parents classes on Saturdays to help them become more competent at helping their children. Clearly, administrative support was needed for these changes, including release time for teachers to plan changes in their classroom routines, a professional library, richer classroom materials, and inservice programs for teachers that focus on the pedagogy of mathematics. A mathematics clinic freeing teachers from study hall to staff the clinic and establishing a dialogue among teachers of mathematics from the 3rd to the 12th grade were seen as potential solutions.

- *How might relationships among teachers, parents, and students be improved?* Teachers and students both need to work on relationships in the classroom. Community-building activities should be added to classroom routines. The school could host an open house when parents could drop by any classroom at any time during the day.

By participating in this research process, teachers, students, and parents were able to understand better the different perspectives that they all held about mathematics at City High and were able to develop recommendations for change. The Task Force's Final Report (Biklen et al., 1992) noted that "our recommendations aim to change what currently seem to be normative values about mathematics at our school. We hear students focus on 'getting it.' We want to change this norm to 'thinking through mathematics'" (p. 25). Over time, the school moved to meet many of the recommendations. The site-based school improvement team used the recommendations as a starting point for many schoolwide discussions. The mathematics department also used the recommendations as a basis for discussion. At the suggestion of the mathematics department, laboratory periods were added to the first-year algebra courses so that more diversity in instructional strategies could be employed. The school began to investigate the use of 90-minute periods for all mathematics classes. The school and the school district moved to mandate algebra for all students. A parents' open house day was established each semester so that parents could drop in during the day and obtain a sense of what was happening in classes at City High. Faculty and graduate students

from a nearby university were invited to give workshops and to model the use of hand-held technologies in mathematics classes. One teacher began to investigate the use of community building exercises in the context of her mathematics classes. Her success at changing the culture of her classroom to one in which students participate freely and help each other readily led other teachers to adopt this strategy. Ongoing, inservice workshops encouraged teachers to have students write in the content areas. These results created a climate for teachers to rethink their own practices systematically, through cycles of inquiry leading to further changes at both classroom and school wide levels.

CONCLUSIONS

Because action research is grounded in practice, it is more a model of incremental change and growth in knowledge than a fundamental rethinking or restructuring of the entire educational enterprise. Nonetheless, action research can lead to more far-reaching changes in relationships and knowledge because it leads practitioners and researchers to mutually redefine their roles and to share their knowledge with the larger community of practitioners. In each of the three cases, we have addressed the critical issue of keeping the distance and preserving the distinction between researcher and participant. As the distances and the distinctions blurred, collaborative team inquiry nurtured and supported the willingness of teachers to take risks in their classes by trying out innovative strategies without the promise of success along the way. The speed with which these teachers changed their teaching practice depended on the cycle of collaborative data collection and analysis. Next steps were predicated on findings based on the teachers' own analysis of the evidence. The complexity of a classroom in flux mandates that the boundaries between research and practice become blurred.

As we looked into single classrooms, we found evidence that the lessons learned from the process of documenting change informed both research and practice. It brought to the forefront issues that needed further research, such as the interaction between group structures and mathematical content. It highlighted good practice such as ensuring that students have multiple opportunities to share their thinking. It opened up new forums for teachers to communicate their findings with other professionals and together to build on those results. In the second study we examined, teachers initiated their own small-scale studies. Here, the

emphases were on defining the research questions that were significant to the individual teacher and on collecting and analyzing data. The juxtaposition of each teacher's beliefs about teaching and learning with the findings from her or his study often caused teachers to begin to rethink and change their teaching practices. As these specific changes were shared among the collective group of participating teachers, more fundamental beliefs about teaching and learning became open to question and discussion. In many cases, this led to broader changes in a teacher's overall practice.

Teachers are asked frequently to change how they teach, but they seldom have meaningful data that encourages them to do so. The teacher-researchers gained an insider view that was a catalyst for change. The lack of distance from the teacher-researcher to the phenomena being studied was related directly to the level of trust in the findings. The collective findings from multiple classrooms began to have meaning for other teachers. The biases of the insider as the researcher became diminished by the diversity of sites and the multiplicity of teacher-researchers across many settings. As more teacher research becomes reported in the voices of the teacher and less in the voices of the university researchers, we are beginning to forge more equitable, collaborative relationships that seek to respect practice-based, teacher-generated knowledge seen in newly emerging forms.

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